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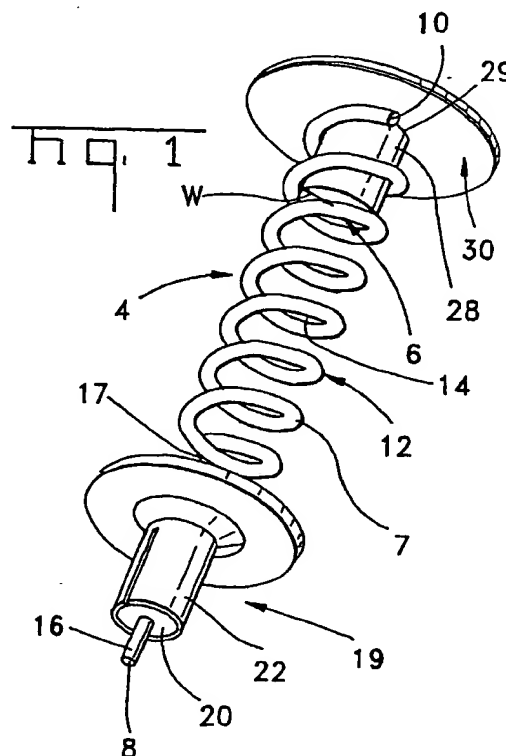
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(54) **Multiple band antenna**

(57) A dual band antenna includes a first conductor (4) in the form of a wire (7) wound in a helix, and a second conductor (6) in the form of a short stub inserted into the helix at a free end (10) thereof where the helix is adapted to operate substantially at a first operating frequency range and the second conductor electromagnetically couples with the first conductor for intrinsic operation at both first and second frequency ranges so that a particularly simple, reliable and easy to manufacture dual frequency band antenna is provided.



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## Description

[0001] This invention relates to an antenna for receiving at least two frequency bands, in particular for mobile communications devices such as cell phones, paging devices, GPS units, computer networking devices etc..

[0002] A dual frequency band antenna system is described US 5,717,409. In this reference, an antenna for receiving and transmitting operating frequencies around 850 MHz (first frequency band) and around 1900 MHz (second frequency band), corresponding to the operating frequencies bands of cell phone (according to the standard AMPS) and personal communications systems (PCS) respectively. In view of the different operating frequency bands of different communication systems, and the desire to have compact communications devices able to operate with a multiple of these systems, there is a need for antenna systems to receive or transmit at least two frequency bands that are not necessarily harmonic multiples. In US 5,717,409, the dual frequency band antenna system comprises a first retractable rod and a second conductor comprising a helix concentrically surrounding a portion of the rod, both rod and helix interconnected to a mobile phone through a matching circuit of the phone. Each of the antennas operate at first and second frequency bands.

[0003] With regard to the helix there are some disadvantages. In particular, the helical antenna is difficult to tune for operation in different phones, which have different electromagnetic characteristics. Mobile phones form part of the "antenna system" and the particular construction of a phone (design of the ground plane etc.) affects the frequency response of the antenna. Antennas thus often need to be tuned for operation in a mobile communications device of a particular construction. The number of turns of the helix may be adjusted to tune the antenna to a particular mobile communications device. The latter is however a difficult and expensive process, particularly for mass production. Another disadvantage of this system is the need for a matching circuit to perform the dual frequency band function.

[0004] It would be desirable to provide a simpler, compact and more cost-effective to manufacture multiple band antenna for mobile communications devices.

[0005] It would be desirable to improve performance, in particular gain, bandwidth and VSWR of a multiple band antenna in an intrinsic, simple and cost-effective manner.

[0006] It is an object of this invention to provide a cost-effective, compact and reliable multiple frequency band antenna for mobile communications devices.

[0007] Objects of this invention have been achieved by providing the antenna according to claim 1. Disclosed herein is a multiple frequency band antenna for mobile communication devices operable at least at first and second frequency bands, comprising a first conductor wound in a coil in the form of a spiral or helix around and along a longitudinal axis, the conductor of the helix sep-

arated from the longitudinal axis by a spacing that defines a central cavity portion, the first conductor extending from a connection end for connection to a signal processing circuitry of a mobile communication device, to a second free end, wherein the antenna further comprises a reactive element or a portion thereof positioned substantially immovably within the helix cavity portion, the reactive element and first conductor adapted to be electromagnetically coupled such that the first conductor and reactive element are operable at the first and second frequency ranges, where the frequencies of the second band are higher than the frequencies of the first band. Advantageously therefore, a particularly compact, simple and reliable antenna for intrinsic operation at multiple frequency bands, is provided. The antenna response can be accurately controlled and tuned for optimal performance in a mobile communication device.

[0008] The length of the reactive element in longitudinal direction may be less than the length in the longitudinal direction of the first conductor.

[0009] The first conductor comprising the helix has an electrical length around 1/4 of the wavelength of the first center frequency (for example 850-900 MHz). The reactive element positioned within the helix electromagnetically couples with the first conductor such that the antenna intrinsically resonates at both first and second frequency ranges. The length and cross-sectional area of the reactive element may be adjusted to tune and optimise performance of the antenna at the first and second center frequencies for operation in a mobile communications device of a particular construction.

[0010] The reactive element may be a second conductor, for example in the form of a cylindrical rod. It is also conceivable to provide the reactive element from a non-conductive material, for example with inductive properties. The reactive element may comprise a flange, for example a circular flange extending from a cylindrical rod forming the reactive element for positioning against the end of the first conductor so as to accurately position the reactive element within the first conductor, in particular such that the overlapping length of first conductor and reactive element is accurately defined in a simple manner. The first conductor may, or may not be, electrically connected to the reactive element in the form of a second conductor at the end of the first conductor, for example electrical contact occurring between an outwardly extending flange of the second conductor abutting against the end of the first conductor helix, or alternatively the second conductor may be fixed via a dielectric in a non-conductive manner to the end of the first conductor helix. The second conductor, for example in the form of a rod, may be coated or positioned in a dielectric, where for example the outer diameter of the dielectric fits snugly within the cavity portion of the helix at the free end thereof such that the second conductor is radially located with respect to the first conductor and electrically insulated (except possibly at the first conductor free end). A particularly simple, compact

and robust dual frequency band antenna is thus provided.

[0011] In order to optimise the antenna operation at both frequency ranges, the antenna may be tuned by varying the dimensions of the reactive element in particular the length and/or cross-sectional area or diameter. The antenna can thus be easily tuned for installation in mobile communications devices having different electromagnetic characteristics.

[0012] In another embodiment, the second conductor may be provided as a continuation of the end of the first conductor, bent into the end of the helix cavity portion for a particularly cost-effective arrangement. In the latter embodiment, the need for a separate reactive element such as a second conductor and dielectric therearound to support the conductor is eliminated.

[0013] The first conductor may for example be in the form of a wire, such as a cylindrical or square profiled solid metal wire wound in a helix having a certain pitch and radius. In the second embodiment where the first conductor is a wire, a certain length of the end of the wire may be bent into the cavity portion of the helix and extend along the center or longitudinal axis of the cavity, although it is also conceivable to position the second conductor in the cavity portion off-centre.

[0014] The connection end of the antenna may (but not necessarily) be in the form of a coaxial connection. The first conductor connection portion may form the center conductor for connection to the center contact of a coaxial connector. Where the first conductor is in the form of a wire, the connection portion thereof may simply be a short length of straight wire extending in the longitudinal direction for example for plugging or soldering or otherwise fixing to a center conductor of a coaxial connector element or other conductor such as a PCB circuit trace. The first conductor connection portion may be arranged in a dielectric to position the center conductor with respect to the coaxial connector or other connection. The antenna helix and reactive element may be wrapped or coated or overmoulded in a dielectric outer sleeve (radome) that has good electrical properties (e.g. low dissipative properties) and further protects and holds the antenna together.

[0015] Further advantageous aspects of the invention are set forth in the claims, or will be apparent from the following description and drawings.

[0016] Embodiments of this invention will now be described by way of example with reference to the accompanying drawings in which;

Figure 1 is a perspective view of a first embodiment of an antenna according to this invention (shown without outer layer or support);

Figure 2 is a cross-sectional view of the antenna;

Figure 3 is a perspective view of a first conductor of another embodiment;

Figure 4 is a cross-sectional view of the second embodiment;

Figure 5 is a cross-sectional view of a third embodiment;

Figure 6 is a cross-sectional view of a fourth embodiment.

[0017] Referring to the figures, a multiple frequency dual band antenna 2, 2' comprises a first conductor 4 and a reactive element which may be a second conductor 6, 6' but could also be a non-conductive element with inductive properties. The first conductor 4 extends from a connection end 8 to a free end 10, the connection end for electrical connection to signal processing circuitry of a mobile communications device (not shown) such as a mobile telephone.

[0018] The first conductor 4 is in this embodiment in the form of a cylindrical wire 7 comprising a coil or helical section 12 extending around and along an axis (A) in a longitudinal direction (L). The coil or helical section 12 is provided by winding the first conductor in a helix having an inner diameter (D) and a pitch (p) between successive coils or turns of the helix. The helical section 12 defines an inner substantially cylindrical cavity portion 14 around the longitudinal center axis (A). The first conductor may also be wound around in a square, polygonal, elliptical or other shape to define a non-cylindrical cavity portion. While a regular helix is preferred, it is possible to have a varying pitch between turns of a coil, and/or it is possible to have a coil with varying diameter (e.g. a conical shape).

[0019] While the first conductor 4 is preferably a solid metal wire that has a regular helix formed along a section 12 thereof, other forms may be contemplated, for example by providing the outer conductor on a supporting substrate. For example, the first conductor may be printed or deposited as a conductive trace in the shape of a helix wound around a portion of a supporting substrate, such as a tube of dielectric material. Alternatively, a wire or other conductor may be positioned in a spiral or helical form around a tube of substrate. Alternatively, the first conductor may comprise a conductive trace on a flexible film, the flexible film then wound in a helix or bent into a cylindrical shaped and supported by a support element or structure such as a dielectric rod. In other words, while it is advantageous to provide a conductive wire that is particularly cost-effective, the wire being simply wound into a helix or spiral along a section thereof, other means of providing a spiral shaped conductor may be considered to perform the electromagnetic function of the antenna without substantially departing from the overall dimensions or performance thereof.

[0020] The diameter, pitch and number of turns of the first conductor are adapted, in conjunction with the electromagnetic coupling to the reactive element, to provide the first conductor substantially with an electrical length that enables it to resonate at the center of a first frequency band corresponding to the first frequency band at which the mobile communications device operates. In present mobile phone systems, the center frequency of

the first frequency band is approximately 850-900 MHz (depending on the standard).

[0021] The connection end 8 of the first conductor comprises a substantially straight section 16 extending along the longitudinal axis (A) in the longitudinal direction (L) from a connection end 17 of the helical section 12. As shown in figures 2 and 4, the connection end straight section 16 extends into the cavity 15 of a connection piece 19 which comprises an inner contact 13 surrounded by a dielectric 20, further concentrically surrounded by an outer conductor 22 that acts as the outer conductor of a coaxial connection. The end 8 may thus be soldered or crimped or otherwise connected to the center contact 13 of the co-axial interconnection piece or conductor. Alternatively, the end 8 may be directly connected (for example by soldering or welding) to a circuit board comprising signal processing circuitry of the mobile communication device, whereby no coaxial connection piece is provided. The centre contact may also be formed by an integral extension of the connection end 8, as indicated in figure 1. The connection piece is provided with a mounting flange 24 for securing on or around the edge of a cutout or hole in the casing of the mobile communications device or for lodging in a base 25 that may be fixed to a cap of the antenna. The assembled antenna as shown in figures 1 and 4 can be mounted to a mobile communication device whereby the connection piece 19 plugs to a complementary connector of the device.

[0022] Referring to figures 1, 2, 5 and 6, the reactive element 6 or a section thereof comprises a length (1, 1', 1'') of conducting, or material with inductive properties in the form of a rod (that in this embodiment is cylindrical but may also have a cross-sectional shape that is polygonal, elliptical or otherwise) that is inserted in the cavity portion 14 of the first conductor at the free end 10. The reactive element or portion thereof positioned in the cavity portion extends therein along a length (1) starting from the free end 10, although the reactive element could also be positioned below the free end 10. The reactive element could also have a portion extending a length (h) outside of the cavity portion, above the first conductor free end, as shown in figure 5. The length (1) of rod has a diameter or width (d) smaller than the diameter or width (D) of the cavity portion 14 such that a dielectric spacing (W) is provided between the second and first conductors.

[0023] The diameter (or width) (d) and/or length (1) of the second conductor 6 may be varied in order to tune the antenna for operation around both first and second center frequencies of first and second frequency ranges of operation of the mobile communication device taking into account the electromagnetic characteristics of the mobile communication circuitry and device. The second frequency range may for example be that of the personal communication system (PCS) with a center frequency of approximately 1900 MHz. The frequencies of the second range are higher than the frequencies of the first

range.

[0024] In order to position the reactive element within the cavity portion such that it is aligned with, or parallel to the longitudinal axis (A) (when offset), a dielectric jacket 28, 28', 28'' is positioned around the second conductor and fits within the cavity portion 14 thereby radially locating and insulating the reactive element with respect to the helical portion.

[0025] Referring to figures 1, 2, 5 and 6 the reactive element may be provided with a radially extending flange 30, 30', 30'' at the top end thereof that extends over the free end 10 of the first conductor for providing a shoulder 31, 31', 31'' that accurately locates the second conductor at the first conductor free end. This ensures that the depth into which the reactive element 6 is inserted in the cavity portion 14 is accurate and can be repeatably effected in a simple manufacturing process. The immovable fixing of the reactive element to the first conductor also provides a well controlled and reliable antenna operable in multiple frequencies.

[0026] The free end of the first conductor 10 may conductively contact the reactive element (which may be a second conductor) at the top end 29, but it is also possible to provide the flange 30, 30', 30'' as part of the outer dielectric piece 28, 28', 28'' whereby the second conductor is not conductively connected to the first conductor. The assembly shown in figure 1 may then be covered in a protective layer 38 that for example may be a radome or dielectric tube positioned thereover.

[0027] The above described arrangement enables provision of a multiple frequency band antenna that may be easily tuned and in particular that is cost-effective and easy to manufacture while providing a particularly reliable and robust construction.

[0028] With reference to figures 3 and 4, in the second embodiment 2'', instead of providing a separate reactive element (in the form of a second conductor) the second conductor 6'' is an integral extension of the wire 7, bent into the cavity portion 14 from the free end 10 of the first conductor. The antenna frequency response may be tuned by adjusting the length (1'') of the second conductor extending within the cavity portion 14. This embodiment is particularly simple and cost-effective to manufacture, reducing the need for a separate reactive element such as a second conductor and dielectric positioned therearound.

[0029] In the above described embodiments, it is also possible to insert or overmould a dielectric (tube, rod or other structure) in the cavity portion, for example in order to provide a support function for mechanically strengthening the antenna.

#### Claims

1. A multiple frequency band antenna (2, 2', 2'', 2''') for mobile communication devices, comprising a first conductor (4) extending from a connection end (8)

for connection to a signal processing circuit of a mobile communication device, to a free end (10), and having a section (12) in the form of a coil or helix extending around and along a longitudinal axis (A), the conductor of the helix section (12) separated from the longitudinal axis by a distance that defines a central cavity portion (14), wherein the antenna (2, 2') further comprises a reactive element (6, 6', 6'', 6''') or a section thereof positioned substantially immovably within the cavity portion (14), the reactive element (6, 6', 6'', 6''') and first conductors (4) adapted to be electromagnetically coupled such that the antenna is operable at the first and the second frequency ranges, whereby a center frequency of the second range is higher than a center frequency of the first range.

2. The antenna of claim 1 wherein the first conductor comprises a wire (7) that has a portion wound into the form of the coil.
3. The antenna of any one of the preceding claims wherein the reactive element comprises a second conductor (6, 6', 6'', 6''').
4. The antenna of claim 3 wherein the second conductor (6, 6', 6'', 6''') is conductively connected to the free end (10) of the first conductor (4).
5. The antenna of any one of the preceding claims wherein the connection end (8) comprises a substantially straight section (16) of conductor extending into a connection piece (19) adapted to secure and position the antenna to a mobile communication device.
6. The antenna of the preceding claim wherein the connection piece (19) comprises a dielectric (20) concentrically surrounding the straight section (16).
7. The antenna of the preceding claim wherein an outer conductor (22) concentrically surrounds the dielectric (20) of the connection piece (19).
8. The antenna of any one of the preceding claims wherein the reactive element (6, 6', 6'', 6''') or section thereof in the cavity portion is surrounded by a dielectric (28, 28').
9. The antenna of any one of the preceding claims wherein the reactive element (6, 6', 6'', 6''') is a part separate from the first conductor (4) and assembled thereto, the element having a flange or shoulder (31, 31', 31'') abutable against the free end (10) of the first conductor for positioning thereof in the cavity portion in a longitudinal direction (L).
10. The antenna of any one of claims 1-6 wherein the

reactive element comprises a second conductor (6'') integrally extending from the first conductor (4).

11. The antenna of the preceding claim wherein the second conductor is bent from the free end (10) of the first conductor into the cavity portion (14).
12. The antenna of any one of the preceding claims wherein the reactive element (6, 6', 6'', 6''') has a length (1, 1', 1'', 1''') in a longitudinal direction (L) that is less than the length in the longitudinal direction of the first conductor (4).

